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the further backward steps toward the simple condition of Argynnis—that is, toward the extinction of the vernal series—it would be hard to conjecture, without treading on insecure ground; rather let us leave that to the future development of parallel facts. —*Menton*, *France*, *April*, 1872.

ON THE GEOLOGY OF THE ISLAND OF AQUIDNECK AND THE NEIGHBORING PARTS OF THE SHORES OF NARRAGANSET BAY.*

BY PROF. N. S. SHALER.

General Topography.—The contour of the shore at this point of our coast at once indicates some peculiar features in the history of the rock masses in which it lies. A great indentation of the coast line having a width of twelve and a depth of over twenty miles, cut here and there with narrow islands and running up into the land in long river-like arms for many miles beyond the limits of its main area, Narraganset Bay, leads us to seek for some forces operating in its formation which were not at work, at least with the same energy, in the region of shore more to the southward and westward. A glance at the general topography will show us more clearly what is to be regarded as peculiar and requiring an explanation from the ancient history of this region.

Nearly the whole of the excavation of Narraganset Bay lies in a region commonly known as Carboniferous.† The great excavations of the Chesapeake and Delaware lie altogether in a region of soft, easily disintegrated material and are thus not comparable with what we have here. The valleys of the Connecticut, the Hudson and the Thames, nearer to the region we are studying, are in the same sort of rocks, or those of nearer equivalent hardness, and are therefore more likely to give us a measure for the forces acting here. But we find that these latter indentations have the simple structure of river excavations presenting, it is true, the character of valleys which have been subjected to other eroding forces than those which have come from flowing water, but still being single and rather narrow indentations in the axis of considerable streams. As we go to the north and east beyond Narraganset Bay, we find indentations of the same general character; at first, obscurely on the southern shore of Massachusetts, but in great abundance and of a perfectly comparable shape on the coast of Maine and the whole shore of the continent to the northward. Thus we see that this Bay is, in fact, the southernmost point of the fiord structure on our coast and is on this account a favorable point for the examination of the causes of the formation of that type of coast line. If we take a number of sections across the whole of the Bay at several points, say at the mouth, five miles from the southernmost point of land, again parallel thereto through the centre of the town of Newport, and further on in succession in an east and west direction through the upper part of Newport island and the island of Prudence; through Bristol and lastly through Fall River, we shall see by these diagrams that the bay gives us a number of furrows and ridges having each a width of from half a mile to five miles and a height or depth from the bottom level of from one hundred to four hundred and fifty feet.* If, however, we take a section in a general north and south direction through any of these channels of Narraganset Bay, we shall find that it presents us with essentially an inclined plane sloping pretty gradually from the northern or inner end toward the sea on the south. The indentations of these channels into their shores are comparatively few and of no great depth. At some points the original islands have been soldered together by marine drift materials so as to destroy the original simplicity of arrangement, but usually throughout the Bay the contours show us a predominance of north and south reliefs. As will be seen by examining the contour lines of the coast survey map, on the scale of $\frac{1}{10,000}$, the nearer ridges of the principal island conform in course in a general way to the trend of the shores of the main islands; showing thereby that it is to some very general action that we owe the existence of these north and south trends.

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* This and the papers to be hereafter published in the same series, are extracts from a Report to Prof. Benj. Pierce, Superintendent of the United States Coast Survey, and are made public by his permission.

† It will hereafter be shown that a very large part of this region generally mapped as carboniferous is in all probability of a very much earlier age. The evidence goes to show that it is a member of the Cambrian series.

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*Three of these transverse sections are given in the diagram Pl. 6. It will be seen that each great channel is a broad but relatively shallow excavation. The drawings from which the sections were made were carefully prepared from the records at the Coast Survey Office in Washington.

It will be noticed that the island has no streams of considerable size; none, in fact, which could have been competent to create the wide and deep depressions we find in the larger valleys of the island by direct abrasion. In some of the minor valleys near the shores, as at the glen on the east side of the island, we have real stream valleys with the normal V-like excavations, but in the larger depressions occupied by the streams the form is very much more rounded and the size usually many times as great, giving broad U-shaped troughs, in which the streams, though in fully close contact with the bed rock, have very little effect upon it. They are manifestly incapable of creating the valleys in which they flow. To account for these depressions we are forced to suppose either of several things; we may suppose that the valleys are the relics of the topography which may have existed here before the Bay was formed, and that the streams which made them gathered their volume in the land which then occupied the space where the waters now lie and a part of the region beyond; we may seek an explanation of their formation in the action of the sea during a former period of partial submergence, a probable source of valley-making, according to the view of many geologists, or we may perchance find that to the erosion of the ancient glacial streams we owe the development of what the brooks only began.

The first supposition is manifestly inapplicable to a number of the valleys of the island, and these among the most important; that which owing to the want of any well established name has been termed the north valley, being that occupied by the stream which debouches just south of the Aquidneck coal mines, does not extend across the island but has its head within fifty feet of its highest hill. On the part of the island to the south of this valley we have several considerable depressions of the same character. Only one of these, that which lies immediately to the north of Newport, is continued clear across the island, but even here the central part of the valley lies so high as to afford hardly a reasonable impression of its having been the valley of an ancient river. A careful consideration of the question has led me to conclude that this hypothesis is inapplicable to any of the valleys of the island. The question of the marine origin of these depressions is easily dismissed. If competent to produce these valleys we should find the sea still at work extending their contours at the point of contact of sea and land. It is sufficiently evident that no such action is now going on. The sea is now making slight inroads upon the land along nearly the whole shore of the island, but the slight waste is not taking place in any greater measure at the mouths of these valleys than at other points. I am inclined to think it eminently probable that these valleys are the result of the amplification of the original stream excavations, by the action of the moving sheet of ice which we shall see there is abundant reason to believe to have rested on this region during the drift period. Long before the present topography was established, probably at a time so remote that the present surface was buried more than one thousand feet beneath accumulations, which have since been worn away, the island had already been separated from the main land. The ice period found certain valleys already cut in the rock, their general course coinciding pretty closely with the direction of the flow of the ice, as will be seen by examining the indicated direction of the ice as determined by the glacial scratches. It is eminently probable that the glacial sheet was pretty nearly level on its upper surface, not having that surface conforming to the hills and valleys which lay beneath. It is evident that where the stream lay deepest the wearing would have been the greatest, for the rate of motion being the same, the wearing of a glacial stream is in proportion to the weight it brings upon equal areas. Thus the valleys would have been deepened and widened until out of proportion to the magnitude of the streams of water which course through them since the glacial sheet went away.

The importance of this consideration has been overlooked; it needs to be considered if we would form clear ideas of the cause of the irregularity in the excavations of all glaciated regions. Sometimes this great difference in the erosive action may be in part attributed to the difference in hardness of the rock acted on. But that this is not the principal cause is shown by the great irregularity of glaciated surfaces and underlaid by the most uniform syenites. In ordinary ærial erosion the beds of the streams are generally kept away from the rock by a padding of debris; but in glacial action these protective agents in running streams become the very sharpening of the ice tool and do the work of erosion instead of protection. By reference to the diagrams (Plates 6 and 7), it will be seen that the channels between the islands have an average depth of about one hundred feet below the water line. They gain their depth quite suddenly and then preserve their gentle slopes across their whole breadth. Their variations in depth may sometimes be connected with a variation in the hardness of the material in which the excavation is made.*

Since the formation of these depressions a considerable amount of filling has been going on which has doubtless done much to modify the form of the bottom and diminish its depth. There are no data for estimating the amount of the accumulation; it has probably not exceeded an average of one hundred feet. Although not expressly made for that purpose, the diagrams also show that the land surfaces are considerably more irregular than those caused by water; water action when the land is buried beneath it tends to make the surfaces uniform while it works to the opposite effect when it acts upon the land lands. There are reasons to believe that the channels to the east and west of the island were occupied by distinct glacial streams for a short period towards the close of the last ice time. The duration of these local glaciers must have been short, inasmuch as the distinct termina lor lateral moraines are few and indistinct.

Excepting the extreme ends of the island the topography is of the simplest character; the broad valleys have slopes of remarkable similarity showing that the material in which they are excavated must have a tolerably uniform consistency. The extreme southwest and northeast ends of the island have contours which contrast remarkably with the middle region. The region known as the neck, lying just south of Newport and the harbor thereof, is one of the most irregular surfaces in New England. At first sight it seems a mere confusion of ice-worn rocks and transported masses piled without order. A little examination shows, however, that here too we have a set of valleys which have a prevailing north and south course, the sides and bottoms of which have been worn into the irregular shapes, which give the chaotic look to the surface, by the action of the flowing water and the old ice mass. The rock being of very varied hardness has worn with different rapidity at different points and so has come to have a very rugged surface. The lines of fault indicated in the diagrams† bring up into contact with this irregular surface the beds of the coal formation, materials as homogeneous as the others are variable. The homogeneity in the character of the latter rocks has caused them to wear uniformly and so to give a very even surface to the country they underlie. This uniformity characterizes all the region between the Lilly Pond and Almy's Pond on the south and the bay known as Blue Bill Cove on the north, with the exception of the strip lying east and west between the Paradise and Purgatory rocks on the east and Miantonomi Hill on the west, wherein there are several exposures of conglomerates and slates which, wearing unequally, have given a broken and irregular character to the surface.

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*The great valleys which now form the Bay were doubtless originally the insignificant troughs of small streams which have been developed under the conditions above indicated.

† These diagrams will be given in the next number of this Journal.

At the extreme northern end of the island, between Blue Bill Cove and the portion of Narraganset Bay known as Mount Hope Bay, there is a small area of the same character as that to the south of Newport, brought up by a fault into contact with coal-bearing rocks. Here also the irregular hardness of the rock has caused it to wear very irregularly.

The continuous sheet of superficial accumulations hereafter to be described does not have any considerable effect in altering the contour of the surfaces except in the finer details of particular points. On the west shore of Blue Bill Cove there is a surface of about one hundred acres which shows a type of topography which occurs at a number of points on our New England shore and is very difficult to understand. The general surface is very nearly a true plane and is underlaid to the depth of more than thirty feet, or below low tide mark by unstratified drift composed principally of materials less than one foot in diameter. The surface of this plain is broken at a great number of points by depressions which recall the character of the sink holes of many limestone countries, though no such explanation will possibly apply to their formation. These depressions vary much in size some of them being several hundred feet in diameter, though usually they do not exceed one hundred feet across, and twenty feet in depth. Generally their outlines are rudely circular, though in some cases they exhibit considerable irregularity of form. At some points these cavities are so crowded together that they encroach upon each other and the plain becomes converted into a warped surface of a singular degree of complication. A precisely similar surface occurs on the low terrace to the south of the town of Quincy, Mass. The conditions both of material and environment are the same in both cases.

There are a few possible means of accounting for this arrangement which suggest themselves ; none of them, however, seem quite to satisfy the facts. The most natural conjecture seems to be that the irregularity was made at the time of deposition of the material. Had it taken this shape afterwards the only possible supposition would be that marine currents had produced the excavation during a period of depression. This, however, is distinctly negatived by the fact that the coarse as well as the fine material has disappeared, there being no such mass of boulders on the bottom of the depression as would exist on this supposition ; moreover, it is really impossible to account for the existence of such great eddies in the positions where these great excavations occur, at points remote from large obstacles such as could set great tidal currents whirling. Limiting ourselves to the conditions which could cause irregularities in the deposition of the drift, we still find the matter beset with difficulties. In the first place, it is difficult to see what could have caused such lacunes in the distribution of drift matter, within or on the surface of a glacial sheet. The most satisfactory explanation seems to be that the greater part of the drift which lies here was borne on the surface of the glacier and that these openings in the moraine matter answer to gaps in the ice on the surface of the glacier, caused perhaps by the action of streams such as are often seen to originate on the surface of a glacier and then to find their way in straight shafts to its base. Such cavities would remain even after they became closed or disused, being covered with drift or quite bare, and at the time of melting their place would be marked by just such cavities as these.

Other depressions exist on a larger scale at the points occupied by the several ponds of the island ; none of these ponds seem to be complete rock basins all having, or having had, deep channels connecting them with the sea. Blue Bill Cove seems to be entirely formed by the drift masses which surround it, except when the syenite rock makes a part of its northeast border. Easton's Pond, near Newport, is the next depression to the southward. We have one of the valleys of the island cut down by the glacial stream until its mouth lay beneath the level of the sea ; when the ice disappeared the valley constituted a fiord-like bay. The action of the sea seems to have made two successive beaches across the valley, one about one-half the distance from the present shore to the head of the pond, the other forming the present bathing beach of Newport. South of this point we have two considerable ponds, Almy's and Lilly pond; both of these and the marshy pond just to the west of the latter are glacial excavations. The last is closing by the accumulation of vegetable matter, its waters having become shallow enough to bear an abundant vegetation, which is rapidly converting it into a peat bog. The island is singularly free from perfectly level lowlands, such as are formed by the filling up of old ponds, and the few sheets of water which remain are not disappearing with the rapidity usual in New England.

The process of occlusion in these ponds can be studied to advantage in the marshes between the Lilly pond and Bateman's. The vegetation, consisting of a variety of marsh plants, begins its growth at the shore where there is a sand beach and bold water, but it may be a long time before its foothold can be made good. Some accident such as a landslide or a fallen tree makes a little shelter, so that the plants get a hold in the water. In a short time they make a bed a foot or more in thickness; their roots go so deep that soon they can stand a considerable beat of the wave. The commotions in the water tear away and distribute over the floor of the pond a part of the mass, but it continues to grow and gains on the clear space, often at the rate of several inches a year. Where the circumstances are favorable, we find the mat of plants extending from the shore over the pond, without touching its floor, sometimes for only a few feet, again, at times, covering many acres with its growth. The accumulation of sediment under these conditions takes place in a singular fashion; the mat of vegetation floats upon the surface of the pond, and sinks deeper and deeper as it grows until, finally, it rests upon the bottom. It then continues to grow until it has gotten itself so far above the water, that the vegetation no longer has the necessary amount of water.*

The topography of the island, as a whole, is remarkable for the small extent to which it expresses the structure of the rock below.

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* This process of growth makes the peat bogs of all countries the natural repositories of the implements of man: where a stone tool remained on the surface it was likely to be found again and again, and used until its very chips were worn away. Falling into a bog, slipping through some crevice in its top crust, it sank to a secure hiding place. The fact that implements can penetrate so deeply into bogs makes them very untrustworthy recorders of time. An implement of the stone age may get buried in the solid matter two feet from the surface, while a modern piece of work falling into a more open spot may sink far below it. When the bog comes to be excavated the deeper buried object is naturally, but mistakenly, taken for the older.

When we come to study the disposition of the underlying rock we shall be struck by the great amount of perturbation the beds have suffered; they are thrown into real mountain irregularities. Few parts of the Alleghanies are more seriously disturbed, but the surface preserves no semblance of mountain forms. It does not differ from the shape which horizontally lying rock would give. If the character of the surface had been given by water action, then we should have had something very different from this. The valleys would then have mapped for us the attitude of the strata and the elevations would have been much greater and differently disposed from what they are now. But under the sheet of ice these details of structure lose their value; the ice cannot turn and twist as the water does, only a slight deflection even under the most important resistance can be permitted. The result necessarily is that the glacial stream wears away without much reference to the disposition of the beds beneath the surface. This is a point of more than local importance; it may serve often as a general guide to the determination of the question whether any particular country shows the result of glaciation. When the topography of any region does not express the structure of its underlying materials, in the fashion common to all surfaces of purely aqueous erosion, then there is reason to suspect the action of ice. This suspicion may amount to a certainty wherein the whole topography has been created with the great independence of internal conditions which it here exhibits.

There is a general absence of sand and pebbles in the beaches about this island; this is, probably, primarily due to the fact that drift has not been enough washed over by the sea to remove the arenaceous matter. The sand mass of Nantasket or Lynn beaches alone much exceeds all that exists in the spits and beaches about Narraganset Bay. The small extent to which the drift has been robbed of its sands is due to the original slight submergence of this district; only about ten to twenty feet of emergence is indicated, so the region has not been so much washed over as the region more to the north. There are great bodies of sand on the shores to the north and south; its comparative absence here is to be explained by the want of recent great movements of the land, and the deep water which prevents its movement along the shore from the east or west. As we go south of this region we come into the area of positive subsidence since the glacial period. This change of land is quite as favorable to the collection of sand along the shore line as the process of elevation. In general the existence of great quantities of sand along an ocean shore may be taken as probable evidence of recent geological movements which have enabled the sea to work over a great amount of débris, of which it has left the heavier part where it found it, and has heaped up the lighter parts where its currents naturally swept them. It will hereafter be shown that the whole region of Narraganset Bay has less drift than exists in the regions further to the northward; it also has few stretches of shore which furnish quantities of sand to eroding agents and none of those great rolling beaches, such as abound to the northward where thousands of tons of pebbles, rushing to and fro under the beat of the waves, are gradually ground into sand and mud. The rocks exposed about Narraganset Bay to the full surge of the ocean are mostly stubborn resisters of the waves, and where masses break away they generally fall into deep water where they are not ground up by the waves. There are no currents working along the shore, which are capable of transporting sands from either the Cape Cod shore or the great masses of Long Island. We see that circumstances have coöperated to keep the inlets of this diversified and beautiful region of our shore free from the overwhelming sands, which in the regions a little to the east or west would have soon closed or effaced them. Nothing can be more strikingly contrasted than the topographical results of water in its solid and its fluid states. Where it moves from the land in the solid phalanx of the glacier it rends a coast into shreds, as ragged as a cloud blown out by the wind. In the sea with the ever varying action of waves and currents, it works to restore the uniformity it destroyed before. Its waves dig down the heights and fill up the hollows, its currents build moles across the inlets and give them over to the agents which speedily convert them to marshy plains.

At the close of each of the many great ice periods in the earth's history the fretted line of the fiord zone was probably swept clear of its débris of all kinds. Then began the process of occlusion which continued until the ice came again to renew its work.

In recognizing the harbors and inlets of Narraganset Bay as glacial work, we get an example of the agent which has given nine-tenths of the havens of our seaboards. That the people of the northern part of Europe have been universally maritime is due, in no small degree, to the recurrent ice action of the northern hemisphere, so close is the connection between this most destructive agent and the highest life.

THE NEW IMMERSION ILLUMINATION.

BY R. H. WARD, M.D.

THE new illuminating lens, introduced by Mr. Wenham recently, has proved to be a sufficiently important accessory to the microscope to command more attention than it has yet received in this country. A small plano-convex lens, nearly hemispherical, has the central part of its curvature stopped off with black varnish; and for convenience the part intended to be thus suppressed may be ground away as shown in Figs. 123 and 124, the ground surface being subsequently painted black. The lens thus prepared is temporarily attached by some highly refracting medium, such as

Fig. 123.

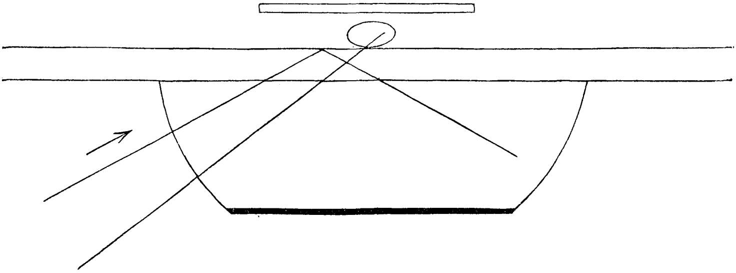

Fig. 124.